

Comparison of Two Similar Species of *Conus* (Gastropoda) from the Gulf of California

Part I: A Statistical Analysis of Some Shell Characters

BY

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(6 Textfigures)

The difficulties experienced by contemporary conchologists in the correct identification of *Conus perplexus* Sowerby, 1857, are not unprecedented, as Sowerby himself attested when he named this gastropod. In his original description (1857, species no. 157, pl. 14) Sowerby remarked, "This shell perplexes me because there is a variety of *Conus puncticulatus* which it nearly resembles." The *C. puncticulatus* of the older writers, however, is definitely not a West American species (Hanna & Strong, 1949, p. 290), while the resemblance which confounds us today is that between *C. perplexus* and *C. ximenes* Gray, 1839, both found in the Gulf of California.

Shell pattern and color are so similar in *Conus perplexus* and *C. ximenes* as to be virtually identical. To separate the two species, it has been the practice to rely primarily on an apparent difference in size and proportion, and on this basis the smaller, fatter species has been designated *C. perplexus*, the thinner and longer, *C. ximenes*. It was my conviction that, if these two "species" are actually distinct, there must be a more objective basis on which to separate them. For instance, I have examined 1448 cones from the Gulf of California, all of which I am satisfied to assign, on the basis of general shape, shell color and pattern, to this complex. But no feature was acceptable as a basis for deciding to which one of the two species a specimen should be assigned. As will be shown below, neither the literature nor considerations of size range, habitat, and geographical distribution provided such a basis.

Perhaps because an insufficient number of specimens was available to the authors, the literature accessible to me does not contribute to a clarification of the confusion. Sowerby's perplexity was as nothing compared to that of Dall

(1910, pp. 219-220). Hanna & Strong (*loc. cit.*, p. 286) have attempted to unravel the synonymy but offer no means of discrimination between the two species.

The size ranges given in the literature are not always applicable. Hill (1959) cites 26 x 16 mm. for *Conus perplexus*, 40 x 20 mm. for *C. ximenes*. Keen (1958, #926, p. 482, and #930, p. 483) gives lengths of 30 mm. (*C. perplexus*) and 42 mm. (*C. ximenes*). Hanna & Strong (*loc. cit.*, p. 290) report dimensions for only one specimen, a large *C. perplexus*, of 41.5 x 22 mm. None of these measurements fits the 78 cones which I collected at San Luis Gonzaga on 27 March 1961, the smallest of which was 40 x 25 mm.

Nor would aperture color serve as a basis for separation of the two species. For, although Keen (*loc. cit.*) mentions difference of color inside the aperture ("blue-violet, deeper within", for *Conus perplexus*; "purple" for *C. ximenes*) as a distinguishing characteristic and Hill (*loc. cit.*) describes both apertures as purple, aperture color in the 1448 specimens varied from white through pink, blue-violet, and purple.

Geographical distribution of the 1448 cones studied covers both sides of the Gulf of California, as well as the Pacific coasts of the Mexican mainland, Costa Rica, Nicaragua, and the Canal Zone (see Figure 1). *Conus ximenes* has been collected at every locality represented, and, although *C. perplexus*, in the collections I have examined, has not been reported south of Puertecitos on the west coast of the Gulf or south of Mazatlán on the east coast, the area in which these cones coexist is still an extensive one.

As for habitat, the cones which I have collected myself (all on the west coast in the north-

ern part of the Gulf) were found almost entirely on sandbars exposed when the tide was out. In this region the ebbing tide, even when not extremely low, uncovers a series of long, narrow sandbars which, as a rule, parallel the shore. They are separated by shallow, even narrower channels. There appears to be a distinct horizontal zonation of species of some of the common molluscan genera, and it would not seem unreasonable to expect a similar zonation in the distribution of *Conus*. And yet, I have collected cones on adjacent sandbars during two consecutive low tides which, on the basis of their proportions, should be assigned to the two separate species. Furthermore, two specimens differing enough to make their assignment to a single species questionable were found side by side at Cholla Bay (Gale Sphon, personal communication).



Figure 1: Map showing the collecting stations of the specimens used in this study.

General Areas	<i>Conus perplexus</i>	<i>Conus ximenes</i>
1 San Felipe	719	20
2 Puertecitos	1	54
3 San Luis Gonzaga		204
4 Bahía Los Angeles		11
5 La Paz		32
6 Puerto Peñasco	150	46
7 Punta Libertad		14
8 Tiburon Island	151	6
9 Guaymas	4	4
10 Mazatlán	17	2
no specific Gulf locality given		13
Total	1042	406

The lack of even one diagnostic feature which I could use as a positive distinction between these two taxa suggested to me the possibility that these cones might actually belong to a single species. This study was undertaken to ascertain by statistical methods whether or not a separation into two groups is valid and, if so, to seek a formula for use in distinguishing between them.

Methods & Procedures

All cones included in this survey were collected in the Gulf of California proper (Figure 1). Specimens from the open oceanic coast of Mexico and its southern neighbors were examined but are excluded from the data presented.

The shells studied are held in the collections of the San Diego Natural History Museum, the Santa Barbara Natural History Museum, and the Department of Zoology of the University of California at Berkeley, and in the private collections of Mr. and Mrs. Emery Chace, Helen DuShane, Faye Howard, Gale Sphon, Kay Webb, and in my own collection. Four hundred six of these specimens were labelled *Conus ximenes*, and 1'042 were labelled *C. perplexus*.

Four measurements (length, width, length of bodywhorl, and apical angle) were recorded for these shells (Figure 2). The linear measurements were made to the nearest half millimeter. All measurements were made to the degree of precision possible with the available instruments: lengths and widths by dividers and a millimeter rule; by a machine designed for the San Diego Natural History Museum; or by a very fine calipers. To measure the apical angles, a goniometer was improvised from a carpenter's bevel and a protractor.

It soon became apparent that neither any single measurement nor any pair of measurements could give an accurate picture of the proportions of an individual specimen due to two inconsistent shell characteristics (both extremely common in the shells labelled *Conus ximenes* and exceedingly rare in those designated *C. perplexus*). The first consists of damage to the spire, altering its shape. This includes broken or worn primary apical whorls, and the effect on the length measurements and on the apical angle is obvious. The second characteristic is the "dropped shoulder" (Figure 3) which can affect the apical angle measurement by making it impossible to have three points of the spire in contact with the measuring instrument. It also distorts the ratio of

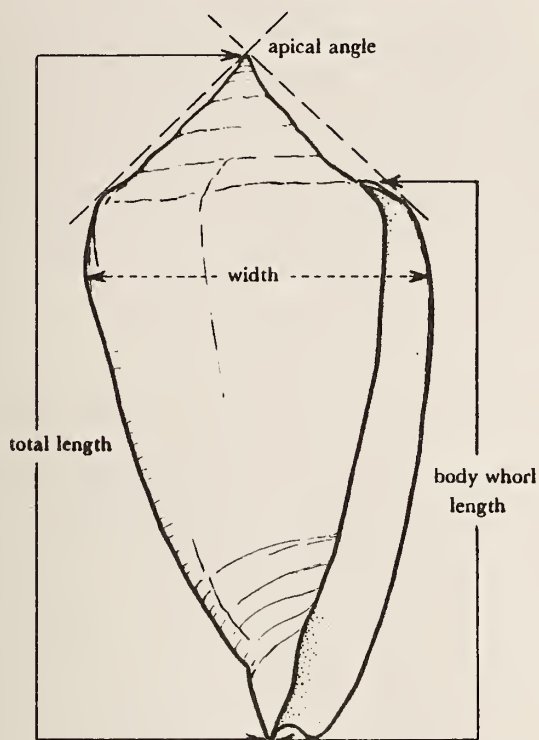


Figure 2: Showing the measurements taken.

bodywhorl length to total length from what might be considered a prototypic proportion. For example, from the data accumulated, one would expect a *Conus ximenes* with a maximum length of 42 mm. to have a bodywhorl length of about 35 mm. and a spire height of 7 mm., whereas, with a dropped shoulder, the bodywhorl length may be only 32 mm. and the height of the spire 10 mm.

To proceed with the statistical operations, it was necessary to equalize the sample sizes. Four hundred six were selected from the *Conus perplexus* data by means of a random number table.

As a first step the following calculations were made:

1. The proportion of spire height to total length was expressed as percent by dividing bodywhorl length by total length (= percent ratio).
2. An Obesity Index was determined by dividing length by width and multiplying by 100.

For these two sets of figures and for the apical angle, histograms were plotted for the 812 shells, without regard to division into species. Each histogram showed a bimodal curve, indicating the possibility of two distinct groups. Figure 4 reproduces the histogram for Obesity Index.

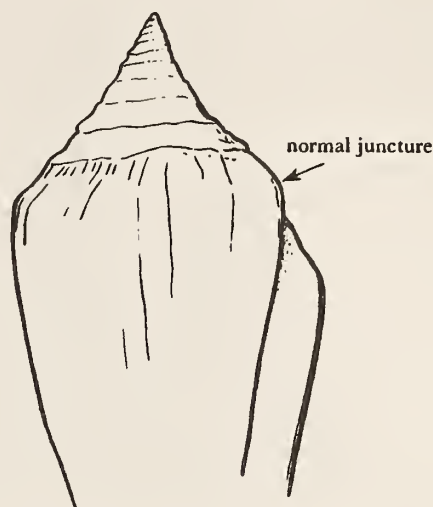


Figure 3: *Conus ximenes* GRAY, 1839. Dropped Shoulder. (compare with Figure 2)

Next, histograms were plotted for each set of figures on the basis of the original separation into species made by collector or curator. In each case there was a central overlap that was too extensive to provide any line of demarcation between the two groups, and, for the percent ratio and apical angle, the range of *Conus ximenes* encompassed that of *C. perplexus*. As an example, the histogram for Obesity Index is given in Figure 5.

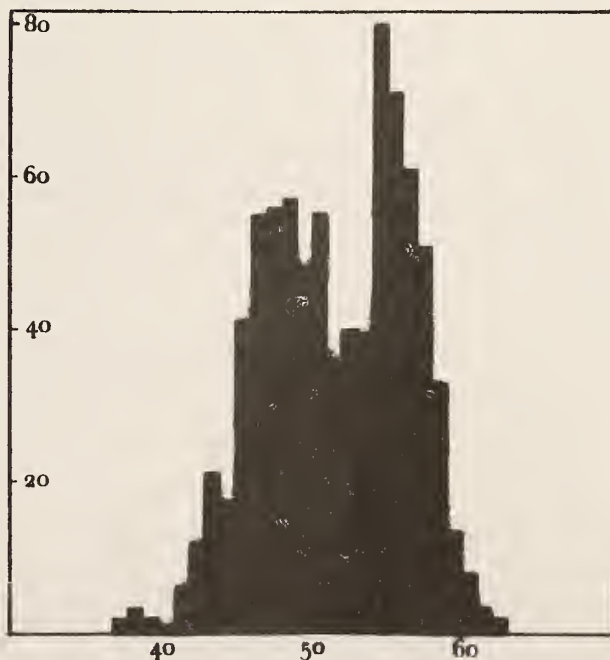


Figure 4: Histogram of Obesity Index of 812 Shells recorded without regard as to species.

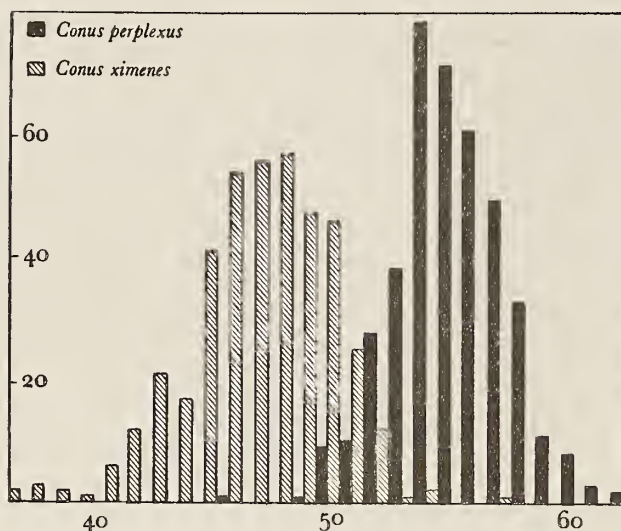


Figure 5: Histogram of Obesity Index of 812 Shells, recorded separately for the two species.

Scatter diagrams were then drawn, correlating each set of figures with length. On the diagrams for the apical angles and for the percent ratio, the overlap remained too great for any separation. The diagram for Obesity Index, however, showed a clearer gap between the two groups. I then prepared a correlation diagram for the 812 shells (406 of each species) based simply upon length and width. This diagram showed practically no overlap, and the two estimated regression lines seemed distinct enough to serve as a basis for further statistical tests.

The length-width measurements were then subjected to multiple regression analysis, with width as the dependent variable, on the CDC 1604 computer of Scripps Institution of Oceanography (Dr. E. W. Fager). The following statistics were obtained.

	<i>Conus ximenes</i>	<i>Conus perplexus</i>
Regression Equation	$W = -170.903 + 0.51875 L$	$W = -61.809 + 0.58126 L$
Regression significant at:	<0.0001	<0.0001
\bar{L}	40.16	22.25
\bar{W}	19.12	12.31
% variation in width accounted for by length	98.98	95.32
mean value of discriminant function	7.66	1.32

Since the shells had been divided into the two categories, it was possible to calculate a discriminant function (Mather, 1951, pp. 152-159) from the regression coefficient and the variances obtained in the analysis. This may be approximately expressed by:

$$\text{Discriminant Function} = X = \text{Length} - 1.7(\text{Width})$$

$$\text{Racial Difference} = \bar{X}_{C.x.} - \bar{X}_{C.p.} = 7.66 - 1.32 = 6.34$$

$$\text{Discriminant Point} = \bar{X}_{C.p.} + \frac{1}{2}\text{Racial Difference} = 1.32 + 3.17 = 4.49$$

The discriminant function is applied in the following manner: any specimen for which X (length minus 1.7 times width) is greater than the discriminant point (4.49) may be assigned to *Conus ximenes*; specimens with a value of X below 4.49 are assignable to *C. perplexus*.

The probability of misclassification is given by the P associated with t (809 df) = 2.046 (p = less than 0.025). The discriminant function is therefore a very good basis for classification.

Results

Both sets of cones mentioned above (those taken on adjacent sandbars and the two that were found side by side) prove, by the application of this function, to have been correctly assigned to the two separate groups.

In addition to the statistical information, examination of these 1448 cones has revealed one shell characteristic that is almost fool-proof for the visual separation of *Conus perplexus* and *C. ximenes*, i.e., the configuration of the posterior notch at the top of the body-whorl as it diverges from the spire to form the outer lip. It is easily recognizable when looking directly down at the spire (Figure 6a) or straight at the lip edge of the body-whorl (Figure 6b).

In *Conus perplexus* the line formed by the notch is recurved (Figures 6a, 6b). In *C. ximenes*, in contrast, the line is practically straight and usually oblique (Figures 6c, 6d). Although here, too, *C. ximenes* is exceedingly variable, careful inspection should eliminate confusion between its random curvature and the definite arcs of the notch in *C. perplexus*. I believe that departure from a straight, oblique line in *C. ximenes* is a deviation from the norm as, in the 406 specimens examined, it was accompanied by evidence of aberration or injury in every case.

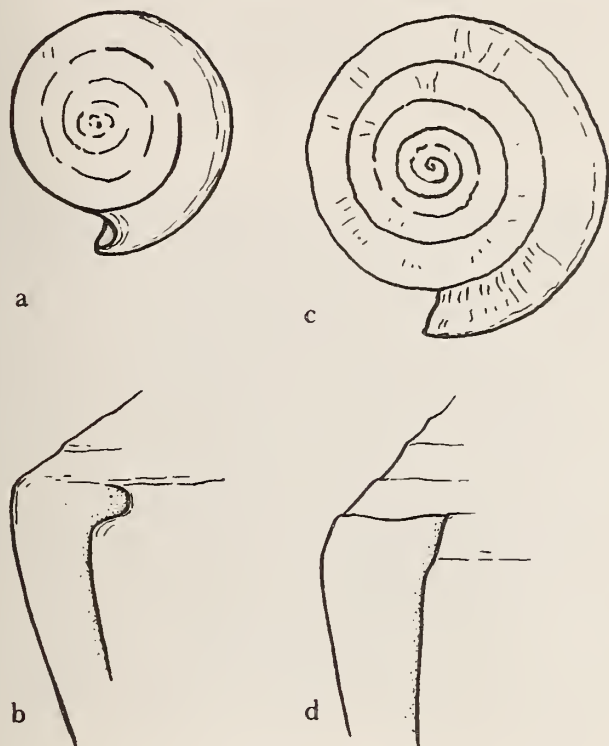


Figure 6: Illustrating Shell Differences
for the two species, *Conus perplexus* SOWERBY, 1875
and *C. ximenes* GRAY, 1839.

a: apical view, b: lip of *Conus perplexus*; c: apical view, d: lip of
Conus ximenes.

Discussion

Two other taxonomic questions have arisen from examination of these collections. One is the need for investigation of the validity for the Gulf of California of the taxon *Conus mahogani* (considered by some authors a race or variety or subspecies, *C. ximenes mahogani* Reeve, 1843). Shells which were labelled *C. mahogani* are not included in this survey, although most of them vary only slightly, if at all, in either appearance or measurements from *C. ximenes*. It is possible that they have been misidentified and should be reclassified as *C. ximenes*.

At the same time there are a few specimens from Panama, labelled *Conus mahogani*, which are entirely different in shape and proportion, color and pattern, from any of the Gulf specimens so identified. Therefore, I suggest that this taxon needs revision. However, this problem is beyond the scope of my studies.

In scrutinizing these collections it has become apparent that there may be still a third species in this complex. About a dozen specimens, labelled *Conus perplexus* in some collec-

tions and *C. ximenes* in others but differing from *C. perplexus* and *C. ximenes* at least as much as those two differ from each other, have come to light. A re-examination of these specimens and a search for more are indicated.

Handling, hunting, observing, and examining so large a number of specimens could hardly fail to raise many questions unrelated to the taxonomic issue. For instance, it is interesting to conjecture why *Conus ximenes* is so subject to aberrations in spire shape. Does this result from damage occurring when the outer lip of the shell is being laid down and is very thin? Of what significance is the fact that, with the exception of the large sampling from Kino Bay, which contains many atypical specimens, there is rarely any deviation from the normal spire shape in *C. perplexus*? Might these phenomena indicate a difference in the manner or rate of growth of these species? I intend to continue observing these animals in the field and in the aquarium.

Both species show a surprisingly small size range in the samplings I have collected in 1961 and 1962. There is no continuous distribution in length, and juveniles are extremely difficult to find. While the data which I am accumulating may not solve these puzzles, they do suggest the possibility of a measure of growth rate.

I also hope to begin a study of the radulae and anatomy of these cones.

Acknowledgment

I wish to express my grateful appreciation to Dr. Eric G. Barham and Dr. David Shepard of San Diego State College for the time and the guidance they have given me; to Drs. E. W. Fager and John MacGowan of Scripps Institution of Oceanography for advice and encouragement; to the museums and individuals who have made specimens available to me; to Mr. Emery Chace for aid with the literature; and to Alan, Lori, and Arthur Wolfson for assistance in collecting specimens.

Summary

The statistical tests reported here have supplied a means of distinguishing between *Conus perplexus* Sowerby, 1857, and *C. ximenes* Gray, 1839, that is reliable 97.5 times out of 100. A visual diagnostic feature has also been described. This study has demonstrated statistically what conchologists have always in-

stinctively felt: that there actually are two populations of cones living side by side in the Gulf of California which, in spite of extremely non-specific characters and habitat, comprise two objectively definable groups.

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A New Land Snail from the Klamath Mountains, California (Mollusca : Pulmonata : Polygyridae)

BY

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Willow Creek, California

(Plate 5)

In the fall of 1956, I discovered accidentally an unusual land snail belonging to the genus *Vespericola*. Because of winter storms and high water, no additional specimens were found until late summer of 1957. In subsequent summers more specimens of this uncommon snail were collected, and more detailed information on its range and ecology was added. Unfortunately, all of this was lost in a fire in 1960. Further collecting since has replaced the loss, and at the present time there are enough specimens on hand for a critical review. A detailed study indicates the advisability of describing this rare snail as a new species.

Vespericola karokorum TALMADGE, spec. nov.

Description of Holotype

An adult specimen with shell of fairly large size for the genus, low-spined, imperforate

except for a small umbilical chink, with a moderately reflected lip and a well developed crescentic, slightly arcuate parietal tooth. The pale brown or tan colored periostracum is thin and exhibits a matte surface which, under magnification of x20, consists of extremely fine transverse wrinkles, in some places broken up into minute granules. Major characteristic ornamentation is the prominent, evenly and widely spaced, scimitar-shaped, fine pointed periostracal hairs, apparently not arranged in any definite geometric order and having their bases flattened in the direction of growth of the shell. Base of lip imperceptibly notched and slightly flared over the umbilical region, leaving a tiny umbilical pit not visible from a direct basal view. Total whorls nearly 6, well rounded, with a well impressed suture. The reflected lip is pale brown and has a form similar to other species in the genus. Maximum diameter, 16.2; minimum diameter, 13.6; height, 8.9 mm.

Explanation of Plate 5

Holotype of *Vespericola karokorum* TALMADGE, spec. nov.

Figure 1. Dorsal aspect. Figure 2. Ventral aspect. Figure 3. Lateral aspect.